NATICK RESEARCH AND DEVELOPMENT LABORATORIES,
CLIMATIC CHAMBERS BUILDING
(Building 2)
U.S. Army Natick Research, Development & Engineering
Center (NRDEC), bounded on the west, south, and east
by Lake Cochituate and on the north by Kansas Street
Natick
Middlesex County
Massachusetts

HAER No. MA-52-A

HAER
MASS
9-NAT,
4A-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENCINEERING RECORD
National Park Service
Northeast Region
Philadelphia Support Office
U.S. Custom House
200 Chestnut Street
Philadelphia, PA 19106

HAER
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4A-

HISTORIC AMERICAN ENGINEERING RECORD

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Kansas Street
Natick
Middlesex County
Massachusetts

USGS Natick, Mass. Quadrangle, Universal Transverse Mercator Coordinates:
19.305180.4684260

DATE OF CONSTRUCTION: 1952-1955, et seq.

ENGINEER/BUILDER: The Ballinger Co., Philadelphia, architects and engineers; George A. Fuller Co., Boston, General Contractor; Arthur E. Magher, New York, erectors, Climatic Chambers Building test chambers and wind tunnels

PRESENT OWNER: United States Army Natick Research, Development & Engineering Center, Kansas Street, Natick Massachusetts 01760

PRESENT USE: The Climatic Chambers Building consists of support spaces and tropic and arctic test chambers which provide a carefully controlled test environment for measuring the efficiency and performance of food, clothing, equipment, and human response to various temperature, weather, and work conditions. The building was constructed for this purpose and continues to be used as such today.

SIGNIFICANCE:

The U. S. Army Natick Research and Development Laboratories is significant primarily for its function and for the buildings and engineering components of the complex which fulfill that function. When formally designated a permanent installation in 1953, it was unique as the first major testing facility in the country to combine research of products, equipment, and materials with the study of human response under virtually all climatic conditions.

Building (Building 2). This building was the most advanced structure of its type when completed in 1955 and is an important work of engineering design. Over the ensuing decades, the mission of the Natick Laboratories has been expanded as research facilities from elsewhere have been consolidated at Natick. The results of studies conducted at the Natick Laboratories have improved field conditions for the individual soldier, and many materials and products tested at Natick have made their way into civilian industry and markets.

PROJECT INFORMATION:

The project being undertaken by the U.S. Army involves modernization of the Climatic Chambers, Arctic and Tropic, within Building 2, and supporting mechanical and electrical control and monitoring systems. These systems are out-of-date or obsolete, some replacement parts are unavailable, and some components of the system contain or use environmental hazards. Both test chambers exhibit deteriorating conditions. The modernization will include replacement of equipment and systems. In addition, interior and exterior finishes will be renovated and a new access door and ramp will be installed for both the arctic and tropic tunnels. (Project Order No. NRDEC 89-183, 28 Dec 1988. Estimated project cost, $15,000,000). This documentation was undertaken between August 1990 and March 1991 under the authority of the National Historic Preservation Act of 1966, as amended (Sections 106 and 110), prior to modernization of the Climatic Chambers.

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I. NATICK RESEARCH AND DEVELOPMENT LABORATORIES, HISTORICAL AND DESCRIPTIVE SUMMARY

The Natick Research and Development Laboratories, now known as the Natick Research, Development & Engineering Center (NRDEC), was authorized by Congress in 1949 with an $11 million appropriation. Construction began in 1952, and in 1953, the Quartermaster Research and Development Center was officially named and designated a permanent installation. It was a major U. S. Army laboratory whose primary mission was the research and development of food, clothing, and personal and organizational equipment vital to the support of the individual combat soldier. Prior to that time, research, particularly during World War I and II, had been scattered at different facilities across the country under the Quartermaster command.

Most of the 78-acre site on Lake Cochituate was donated by the town of Natick. The site was selected in part for its proximity to Boston, 20 miles away, and for its abundant and inexpensive water supply. Construction began in November 1952, and the facility, consisting of ten reinforced concrete buildings, began operations in the summer of 1954. The construction cost was $11 million and followed the designs of the Ballinger Co. of Philadelphia, carried out by the George A. Fuller Co. of Boston, general contractors.

The layout and architecture of the facility was, and is, largely utilitarian in character, but remnants of the preexisting wooded landscape and its setting on a small peninsula along the lake shore create a semi-rural ambience. The laboratory complex buildings completed in 1954 and 1955 included five major research and administrative buildings: the Administration Building (Building 1); the Climatic Chamber Building (Building 2); the Research Building (Building 3); the Development Building (Building 4); and the Technology Engineering Building (Building 5). Among the support buildings constructed were: a boiler house (Building 19); an enlisted man's barracks (expanded in 1978-79); the Hazardous Research Building, now the communications center (Building 8); and the Laboratory Test Building (Building 7).

Major additions to the original facility have included the Engineering Building (1964, Building 36) and the Environmental Medicine Building (1968, Building 42). The facility also owns and maintains four housing areas in four Massachusetts towns: Natick (1974); Wayland and Needham (1958); and Sudbury (1962).

Since 1983, Natick Labs have been one of two facilities (along with the U.S. Army Belvoir Research, Development, and Engineering

Center) under the U.S. Army Troop Support Command (TROSCOM). Natick carries out research, development, testing and engineering in food and food service systems, shelters, clothing systems, airdrop systems and field service equipment to sustain and support the combat soldier. Activities are housed in four prime Directorates: Aero-Mechanical Engineering, Food Engineering, Protection, and Science and Advanced Technology. Responsibilities also include the development of specifications and standards for products and commodities with military applications.

II. CLIMATIC CHAMBERS BUILDING, DESCRIPTION, ORIGINAL CONSTRUCTION, AND LATER MODIFICATIONS

The Climatic Chambers Building of the U. S. Army Natick Research, Engineering & Development Center (NRDEC), Natick, Massachusetts, is located in the southeastern portion of the 78-acre installation. It occupies a prominent site in the layout of the facility and faces north onto a small rotary at the head of a T-intersection formed by C Street and Fourth Avenue. Fourth Avenue, the primary entrance road to the complex, is flanked by the Headquarters Building (Building 1) on the east and the two Research and Development Buildings (Buildings 3 and 4) on the west and terminates at the rotary opposite the main entrance to the Climatic Chambers Building.

The block occupied by the Climatic Chambers Building is bounded on the north by C Street, west by a parking lot and service lane, east by Fifth Street, and on the south by a large, asphalt-paved parking lot. The building's immediate setting is open, with minimal landscaping, including a grass strip along the east side and grass along with a small number of mature shrubs around the north entrance. A service road and asphalt sidewalk abut the building's west elevation, and on the south, the parking lot extends to the building wall.

The Climatic Chambers Building is comprised of a 1-story, T-plan, reinforced concrete building with two steel plate wind tunnels set into the angles of the T, creating a symmetrical, U-plan structure, 231 by 140 feet in size. Essentially unaltered since its original construction in 1952 to 1955, the Climatic Chambers Building is a plain, utilitarian building whose scientific engineering function is clearly expressed in its form, massing, and materials. The building is constructed of 10"-thick concrete slab walls with punched openings and rises from a concrete slab foundation to sheer coping at the cornice of the flat, tar-andgravel roof. Both the arctic and tropic chamber wind tunnel structures are horizontal, standing seam, steel plate shells with square end sections and circular and flared central sections. The building is fairly well maintained. Roof repairs occurred in 1958 and 1979, and the sheet steel was painted in 1971.

The north, main facade, elevation has a central plate-glass-and-aluminum entrance under a rectangular concrete slab canopy on canted supports and set in a slightly projecting and parapeted square bay. Horizontal bands of windows flank the entrance. The original steel windows were replaced in 1981 with extruded aluminum sections. The west and east elevations are nearly identical, consisting of the wind tunnel structures set on a concrete foundation and a concrete slab section at the rear (south) end of the building. An overhead loading door with a 24-light steel sash window in the upper half, and a utility door with a concrete ramp and porch, are located on the west side. The south (rear) elevation is a continuous concrete slab wall with two loading doors (central and at the east end) identical to that on the west elevation. The central door is flanked by rows of four original 6-light steel windows.

The front (north) portion of the T-plan block contains the administrative offices, day room, classroom, dressing rooms, observation rooms, and clothes conditioning chambers. The rear (south) portion holds the mechanical equipment, maintenance area, thermocouple room, and sections of the wind tunnels. Interior partition walls are constructed of concrete block and asbestos board. The interior is basically symmetrical in plan and remains mostly as originally constructed. The most noticeable modification is the removal of partition walls that originally enclosed a calculating room in the central area, converted in 1977 to an open-plan administrative and circulation space.

Interior finishes are functional: linoleum or concrete floors, painted walls, plain door enframements, original hollow sheet metal and later plate-glass-and-aluminum doors, and ceramic tilework in the shower, bathroom, and kitchen areas. The most distinctive finishes are those associated with the testing areas. The clothes conditioning rooms are protected by a composite wall and ceiling comprised of cork and insulation. Recent renovations of the clothes conditioning room on the tropic side included installation of a new door from the administrative area. The insulated refrigerator air-lock doors separating spaces with differential temperature capabilities are typically varnished yellow pine with forged and galvanized steel or bronze hardware, manufactured by the Jamison Cold Storage Door Company, Hagerstown, Maryland.

The Climatic Chambers Building itself was constructed by the George A. Fuller Company, Boston, Massachusetts, following plans developed by The Ballinger Company, a partnership of architects and engineers, 121 North Broad Street, Philadelphia, Pennsylvania. Few changes have occurred since its original construction.

III. ARCTIC AND TROPIC CHAMBERS, DESCRIPTION AND OPERATION

[Note: Sections of text below adapted from Specifications for Construction of Climatic Chambers in Climatic Building for Quartermaster Research and Development Laboratory, Natick Massachusetts, Department of the Army Corps of Engineers, New England Division (1955) and from Operating Instructions for Climatic Chambers at Quartermaster Research and Development Laboratory, Natick, Mass., Arthur E. Magher Company, Inc. (n.d., c. 1955)]

The Arctic and Tropic chambers and associated mechanical and electrical equipment and control and monitoring systems were erected and installed by the Arthur E. Magher Co.,Inc., New York. Modifications were made to fine tune the newly installed systems in 1955/56 following an evaluation undertaken by the Mechanical Engineering Committee, The National Academy of Sciences - National Research Council, Advisory Board of Quartermaster Research and Development. They included augmenting equipment, duct and pipe revisions for the TCE receivers, the venting, air conditioning, rain water, and floor coil systems, and were designed by McConathy, Hoffman & Associates, Inc., 150 Broadway, New York.

The scope of construction services for the two climatic chambers also included insulation and refrigerator doors for the clothes conditioning rooms, dressing rooms, and airlock chambers.

The construction of each of the climatic chambers consists of outer and inner shells made up of hot-rolled steel plates up to 1/4" thick and welded together and reinforced with structural steel members, visible as ridges on the exterior. Wood framing between the walls provides spacing, rigidity, and a sleeve for 12" of insulation. The interior shell has constant temperature steel, sprayed with a rust resisting material along the sides and ceiling. Three observation windows of double-pane glass allow visual access between the test chambers and the adjacent Observation Rooms.

The Arctic and Tropic Chambers are similar except for the size and shape of the By-Pass Sections and the equipment in these sections. The Arctic Chamber is designed to provide and maintain temperatures from -70 degrees F to +70 degrees F, and the Tropic Chamber, temperatures from 0 degrees F to 165 degrees F. Each chamber consists essentially of a four-sided wind tunnel circuit composed of a Test Section on the interior of the building, a Tunnel Section containing the fan on the exterior of the building, and two short connector sections on the north and south. The Bypass Section, which angles either southwest (Arctic) or southeast (Tropic) from the north connector is used for heating and cooling the tunnel. Each chamber has an individual ventilation system, refrigeration and reheat system and floor coil system. The rainwater and humidification equipment service both chambers. The Tropic Chamber has an array of solar radiation lights, installed in 1986.

Each Tunnel Section contains the main 400 horsepower, electric motor driven, propeller type fan (shown as a pointed cylinder in the floor plan) with drive shafting and humidifier sprays downstream of the fan. The main fans, produced by the Jeffrey Manufacturing Company, Columbus Ohio, generate air speeds of 2 to 40 M.P.H. within the Test Section. The humidifier sprays add moisture, when required and as called for by the dew point controller, to maintain the proper humidity within the Test Section.

The Test Section of each chamber, which extends north-south adjacent to the observations rooms, is 60 feet long, 15 feet wide, and 11 feet high (8ft 8in at the sides). It includes the raincourt, bivouac and treadmill areas. The raincourt area is serviced by the rainwater system. The entire floor of the Test Section was designed to be heated or cooled by a floor coil system that is now inoperative. The treadmill area contains two treadmills, (shown as rectangles with x's in the floor plan), one which moves at right angles to the air stream, and the other parallel to the air stream. The two perpendicular treadmills (each 4.5ft x 8ft) are adjustable from a level position to a 12 percent grade. There are four emergency stop buttons in this section for shutting down the treadmills and fans.

Each By-Pass Section, which angles southerly from the main circuit, contains two banks of cooling coils with automatic dampers and eliminators, 40 HP by-pass fan, reheat coils and a sliding door. The sliding door, (shown as a dotted line in the floor plan), can be positioned, in increments, from full flow of test section air through the by-pass coils down to none through the by-pass. Normally this door will be positioned to scoop sufficient air off of the main tunnel circuit as required to maintain temperature and humidity conditions. In this case, the door is positioned so that the scoop area is approximately equal to the alley area in the By-Pass. The by-pass fan can be adjusted by means of a variable speed drive to pass the required amount of air through the cooling and reheat coils for conditioning purposes. One bank of cooling coils is in operation while the other is being defrosted, thus not affecting the condition of the air entering the Test Section.

Chamber conditions are controlled from the Chamber Control Panel located in the machine room on the north side near the dividing wall with room 112 (see floor plan) against the north wall. This panel contains start-stop switches and speed control stations for the main and by-pass fans, air speed meter for indicating air velocity in the test section and dry bulb and dew point recorder-controllers for controlling and recording temperature and humidity conditions in the test section. Sensing elements for the air speed meter, dry bulb recorder-controller and dew point recorder-controller are located in the Chamber at the upstream end of the test section.

Additional control, indicating, and recording instruments for the Chamber are located in the Observation Room. In this room are the start-stop switches, speed control stations and hydraulic pumps for adjusting the treadmills, remote air speed indicator, dry bulb and dew point recorders and emergency stop buttons for shut down of main and by-pass fans. Over time, computerized monitoring equipment has been introduced to the complement of instruments.

The refrigeration equipment and systems were supplied by the Worthington Corporation, an early pioneer in the field of mechanical refrigeration. The primary components of the refrigeration cycle in each case are similar (a list of original equipment appears in Appendix I). Each individual system delivers 600 tons of refrigeration via one 400 ton centrifugal compressor and two 100 ton each reciprocal compressors, which can be operated in any combination. Freon-12 (F-12) is used as both a refrigerant (a liquid that readily absorbs heat by evaporating at low temperature and pressure and gives up its heat on condensing at a higher temperature and pressure) and brine (a liquid cooled by a refrigerant and used for the transmission of heat without a change in its state) in the both chambers, while Trichlorethylene (TCE) is also used as a brine in the Tropic Chamber as a heating medium. The basic equipment, corresponding to the stages of the refrigeration cycle are the shell and tube cooler, the centrifugal compressor, the shell and tube condenser, and the flash chamber. In both chambers, the refrigeration cycle is a compound, closed system.

In the bypass sections of the Climatic Chambers, F-12 or TCE is pumped through tubes in the heat exchanger coils. F-12 evaporates and absorbs heat thereby producing a cooling effect, while TCE produces a cooling effect in the coils after it has been cooled by F-12 in a heat exchanger. In either case, F-12 evaporates by absorbing heat to produce a refrigeration effect.

Depending on conditions required in the chamber, either a single stage or multi-stage refrigeration operation can occur. For the top stage, at higher temperatures, both chambers have two Worthington Model 6 HF 6 High Stage Reciprocating Compressor units with single step unloaders running at 642 RPM each, driven by one 100 HP, 1200 RPM electric motor. The bottom stage, or low temperature machine in the Arctic Chamber is a Worthington Model 54 H Freon-12 Low Stage Centrifugal Compressor running at 5130 RPM driven through a Model CR-6 step-up gear by a 400 HP 1200 RPM Westinghouse synchronous electric motor. The Tropic Chamber Centrifugal compressor is similar, but runs at 5060 RPM, driven by a 350 HP motor. In each case, the F-12 refrigerant vapor is compressed in single or successive stages to the proper pressure corresponding to condensing temperature. In general, the reciprocating compressors are used for light load and moderate temperatures, and the centrifugal compressors for lower temperatures.

The vapor is then drawn into the horizontal tubular F-12 Condenser shell with finned copper tubes arranged for one water pass. F-12 refrigerant flows around the tubes and releases heat to the relatively cool condensing water circulating through the tubes. As the vapor condenses back into a liquid, the refrigerant collects in the hot well chamber and is metered to the flash liquid cooler. In the flash liquid cooler, which has an intermediate pressure, a proportion of the liquid "flashes" off and cools the remainder of the liquid to the temperature corresponding to the flash chamber pressure. The flash chamber increases the efficiency of the system by accelerating the cooling and condensing stage of the cycle. Intercoolers feed into the system at various points to monitor and regulate the temperature of the refrigerant, and oil separators remove lubricating oil from the refrigerant in cycles using the reciprocating compressor.

The reheat systems of the Arctic and Tropic chambers are also similar. Trichlorethylene is used as a brine. It is heated by steam in the brine heater and circulated by means of a reheat coil pump through the reheat coils in the By-pass Section. The main fan circulates heated air to the Test Section. Temperature is controlled, dependent on operating conditions and as determined by operating personnel, by a controller which regulates the flow of steam. It is located at the side of the refrigeration control panel in the machine area.

The floors in both chambers were designed to be heated or cooled by a system of pipe coils below the floor, which is no longer used. The humidification systems use hot water from the building supply which is pressurized to 300 lbs and delivered via four banks of spray nozzles in each chamber. The ventilating systems involve the introduction of air into the alleyway of the By-Pass Section, which is circulated through the Test Section and exits through an air relief damper.

The plant design of the Arctic and Tropic Chambers is engineered to meet test conditions that vary over a wide range of temperature and humidity, wind velocity, and internal loading depending upon the number of test subjects. These factors require that operations be undertaken and monitored manually. While some aspects of the system are automated once test conditions are attained, periodic checking of pressures, temperatures, speeds, and functioning of equipment by operating personnel is crucial to the successful and safe operation of the systems. The manuals supplied with the original equipment articulate this premise and serve only as general guidelines to the overall functioning principles. Data accumulated through experience starting, operating, and stopping the systems and recorded in logs by qualified and experienced refrigeration personnel provides specific guidance and alternative methods for different types of operating conditions. In large part due to the nature of the design of the integrated refrigeration system, no major modifications to the system have occurred, although there has been limited one-for-one replacement of lesser machinery over the last forty-odd years. Changes are well documented in the vertical administration files and engineering drawings maintained in the Climatic Chambers Building.

IV. ARCTIC AND TROPIC CHAMBERS, HISTORICAL CONTEXT

The U.S. Army Quartermaster Corps was created during the Revolutionary War with a mission to provide troop service and supplies. In the twentieth century, as new materials and products were developed by private industry and used or adapted for military purposes, the QM Corps increasingly evolved in its responsibilities to identify and research optimum products to maximize efficiency, survival, and safety for individual combat soldiers and units of military organization. The experiences of World War I and II demonstrated the vital link between industry and military needs.

As new technologies were introduced, many were adapted for military applications, and the military actively encouraged and supported research, development, and production in many areas.

In private industry, the period around the turn of the twentieth century was one in which scientific testing and research and the initiation of industry standards for materials and manufactured goods emerged. Two organizations established before 1900 are of interest with regard to the purpose and functions of the Climatic Chambers. What is now the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) was formed from professional organizations founded as early as 1894, and the American Society for Testing Materials, now the American Society for Testing and Materials (ASTM) was founded in 1898. These groups, along with a multitude of others, helped forge new standards, develop new testing technologies, and introduce a wide variety of products and materials for a range of applications.

Following World War II, a number of changes were made in the military programs involved in research, development, and testing. Efforts to consolidate U.S. Army research, development, and testing activities related to the support of the individual soldier, which were scattered in different states across the country, resulted in the appropriation by Congress of $11 million in 1949, in order to establish a single unified research laboratory at Natick. Further steps towards uniformity were embodied in Public Law 436, effective July 1, 1952, which mandated that Department of Defense (DOD) standardization programs attain the highest practicable degree of standardization of items utilized by DOD. Different military departments were assigned responsibility for specific standards in particular areas. Among those areas assigned to the Army were textiles, thread, leather, paper, rubber, and plastic, all materials manufactured into commodities for the individual soldier's personal or organizational use. An important component of the concept of military standardization was close cooperation between DOD and ASTM. This cooperation, which was already in fact occurring, was viewed as vital to both the national economy and national defense.

An important distinction between civilian and military standardization programs, which remains valid today, was articulated in a series of articles that appeared in the ASTM Bulletin in 1955, the year Natick Labs went into operation. The ASTM was concerned primarily with uniform methods of testing and uniform specification requirements (limitations and applications) for raw and basic materials, as well as certain manufactured items. DOD, in contrast, necessarily dealt with a much broader program. The DOD standardization program encompassed the development of uniform specifications (procurement of supply) for all items of common use in the Army, Navy, and Air Force. This included not only basic materials, but components, equipment, processes, and services. In addition, the program included standardization of engineering practices and procedures essential to the design, procurement, production, inspection, and application of items of military supply. One of the purposes of the program was to consolidate existing specifications in use by various military departments into a single series of specifications (Watts 1955).

In 1955, when the Quartermaster General Research Laboratory at Natick commenced operations, numerous testing facilities designed for different purposes existed across the country. Many were exclusively for, or included capabilities for, climatic testing. Between 1946 and 1955, The Engineering Index listed articles in journals on 16 weather rooms and five aeronautical laboratories simulating low and/or high temperature and high atmosphere conditions. Beginning in 1957, these facilities were listed as environmental chambers. They tested automobile and aircraft parts, radar and other electronic equipment and parts, refrigeration and air conditioning equipment, and similar types of materials and items.

For example, B.F. Goodrich began research on rubber and synthetic rubbers in cold climate conditions in the mid-1930s. Following World War II, when temperatures of 65 degrees below were encountered in Siberia and Alaska, testing was stepped up, and a 50 to 95 degree below cold room for testing automobile parts was constructed in 1947 (Aero Digest April 1947). The Army constructed a chamber to stimulate tropical conditions and representative fungi to study the deterioration of materials such as cork, fabric, plastics, woods, and other basic materials (Industry and Chemistry January 1946), and the Materials Laboratory at the New York Naval Shipyard constructed 14 test chambers to test electronic equipment under different environmental conditions (Refrigeration Engineering, August 1951).

In the arena of research on environment and human physiology and behavior, testing during this period was largely confined to the emerging air conditioning industry. As early as 1931, the American Society of Heating and Ventilating Engineers (a precursor to ASHRAE) conducted tests on comfort and humidity range for domestic and business applications of air conditioning (Fahnestock and Werden, February 1956).

The Arctic and Tropic Climatic Chambers at Natick were, however, the first research and testing facility in the country to merge testing of materials and products with the study of human response under all known ground environmental conditions in the world. As such, it represented a major conceptual shift from prior private industry and military testing approaches and reflected the Army's commitment to outfitting the individual combat soldier, as well as the need of the military to test and modify materials and products, either developed in house or commercially, for in-field conditions.

Like many other similar military and private industry testing facilities, its climate range capabilities recognized the global nature of future conflict possibilities in the Cold War period. The period in which the Natick facility was constructed coincided with the Korean War (1950-1953), with the first successful H-bomb test (1952), and the launching of the first atomic-powered submarine (1954).

Early tests conducted between February and October 1955 included studies of: a protective, acid and fuel resistant suit to establish tolerance limits when worn in hot environments; the encumbrance effect of arctic clothing to establish techniques for measuring the extent to which arctic clothing interferes with a soldier's ability to use his arms, legs, or body; an energy balance study to establish baseline energy relationships of men prior to their exposure to a desert environment; and a study of several lightweight non-fogging facemask models to measure efficiency in protecting the face without causing frostbite at edge areas. These types of studies, designed to determine testing measurement techniques and to study various aspects of the interrelationship between human physiology, the properties of different materials and products, and a wide range of hot and cold climatic conditions, have been the focus of research and development at the Climatic Chambers since the facility's construction. Nearly all personal equipment used by Army and other military soldiers and many materials and items found in the civilian market have been tested at Natick. In addition, the responsibility to provide specifications for items of Army supply has meant that testing results have affected private industrial production geared to meet military demands.

The refrigeration systems of the Climatic Chambers are the prime operational systems in the functioning of the Arctic and Tropic Chambers and ancillary climate-controlled spaces. The major equipment components of the two similar systems were designed and manufactured by the Worthington Corporation. Founded in the 1880s and in business until the 1960s, the company was a leader in the development and manufacture of mechanical refrigeration systems, particularly for large scale sites. The company's status was reflected in the prominent positions held by Worthington management individuals in the refrigeration field. For example, Matthew M. Lawler, vice president and general manager, was elected president of the Air Conditioning and Refrigeration Institute in 1942 (Grant 1942). Based in Newark, New Jersey, Worthington had plants in Holyoke, Massachusetts, Harrison, New Jersey, Decatur, Alabama, and elsewhere, with different divisions for various types of equipment, such as pumps and processed gas compressors. The rights of supply and maintenance for the Worthington Corp. are now owned by the Magnetek Supply Co., Fairfield, New Jersey.

A standard definition of refrigeration is, "the science of providing and maintaining temperatures below that of the surrounding atmosphere" (Gunther 1969). In the last decades of the nineteenth century and the first decades of the twentieth century, mechanical refrigeration developed quickly from a little used luxury to an everyday necessity. Initially, a primary application was for food preservation, both on a relatively small scale and for large refrigerated warehouses. In the twentieth century, air conditioning was among the chief of a rapidly expanding sphere of applications.

One of the most important areas of technological improvement for the refrigeration of large scale installations was the advances in the development of the centrifugal compressor. Research into the use of centrifugal compressors for safe air conditioning application began about 1905. This type of unit had efficiency advantages in providing higher pressures by a multiple staging effect and did not require oil separators for the refrigerant, since no internal lubrication was necessary. Early experiments were conducted by Maurice LeBlanc in 1910-1912 and by others. In 1922, Dr. Willis Carrier made a demonstration before the American Society of Refrigerating Engineers (a precursor to ASHRAE) of a compressor capable of delivering 70 tons of refrigeration. Dr. Carrier was the founder of the Carrier Co., an important refrigerating engineering and manufacturing business. Between the late 1930s and the late 1940s, numerous improvements were made by the Carrier, York, Worthington, Trane, and Ingersoll Rand companies, all of whom introduced successful centrifugal type units adapted primarily for the compression of Freon refrigerants. Among them were a unit introduced by the Worthington Corp. in 1939 that was similar to the Carrier unit.

Breakthroughs in refrigerant development had also occurred in 1931 when the Frigidaire Division of General Motors, in collaboration with DuPont, introduced the Freon family of refrigerants. Freon-11, available after 1933, became the standard for use with centrifugal compressors, while Freon-12 was used for general reciprocating machine duty (Grant 1942; Woolrich and Bartlett 1948).

Little research has been conducted to date on large scale refrigeration systems in the mid-twentieth century. In 1948, one publication on refrigerating engineering estimated that there were approximately 400,000 tons of centrifugal refrigeration installed around the world, divided among approximately 1100 installations. Thus, the typical average installation was between 300 and 400 tons capacity, with very few installations at less than 100 tons (Woolrich and Bartlett 1948). Installations of over 400 tons were used for applications such as air conditioning large commercial and office buildings and to meet industrial needs. Many buildings such as the Chrysler Building, constructed in 1930, and the Pan Am Building, constructed in 1963 in New York City, have still-functioning original systems. The Pan Am Building has three centrifugal units delivering 800 to 900 tons of refrigeration (John Flanagan, personal communication). An advertisement for the Worthington Corp. in a 1956 issue of <u>Refrigerating Engineering</u> states that they had recently installed four compressors and a 1660 ton refrigerating system to provide controlled, near freezing temperatures at the Anhueser-Busch plant in Los Angeles. Worthington offered systems using centrifugal units for ranges of tonnage from 100 to 3500 tons.

Thus by the mid-1950s, large scale installations using centrifugal compressors to lower temperature were widespread. The two 400 ton Worthington compressors, along with the four reciprocating units, comprising the two sets of 600 ton refrigerating systems at the Climatic Chambers are within the normal range of systems being installed at the time. Their importance, therefore, lies in how the system was designed to meet the purpose of the testing facility. The multiple units allow a high degree of flexibility, in that they can function in any combination, including either all on or all off. In addition, whereas standard installations are typically designed to attain and maintain a relatively smaller range of temperatures, the systems' operations of the Climatic Chambers are overall more complex. They require a high degree of expert monitoring due to the wide range of temperatures that can be achieved and the variability possible between the upper and lower ranges.

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(404) 636-8400. Telephone interview with author, March 1991.

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52196
55048
57812
57197
56236

APPENDIX I

LIST OF EQUIPMENT FURNISHED

(Source: Maintenance of Worthington Refrigeration Equipment Manual, c. 1955)

I. Arctic Chamber

(1) F-12 Evaporator

1 - 38" x 11'-0" horizontal double shell type flash liquid cooler. CW-24773.

(2) F-12 Low Stage Compressor

1 - Model 54 H Freon-12 Centrifugal Compressor running at 5130 RPM, driven through a Model CR-7 step up gear by a 400 HP 1200 RPM Westinghouse synchronous electric motor. RW-105629.

(3) F-12 Discharge Gas Cooler

1 - 14" x 4'-0" horizontal double pipe gas cooler. CX-24369.

(4) F-12 High Stage Compressors

2 - Model 6 HF 6 Freon-12 reciprocating compressor units with single step unloaders running at 642 RPM each driven by one 100 HP, 1200 RPM electric motor. HR-9333.

APPENDIX I (Continued)

(5) F-12 Oil Separators

2 - "ACME" 14" x 3'-0" vertical Freon-12 oil separators. B-3443.

(6) F-12 Condenser

1 - 24" x 10'-0" horizontal tubular Freon-12 condenser having 386 finned copper tubes arranged for 1 water pass. F-12 refrigerant is condensed on the outside of the tubes by cool water passing through tubes. CW-24772.

(7) F-12 Intercooler

1 - 24" x 9' - 0" horizontal Freon-12 intercooler. CX-24370.

II. Tropic Chamber

Items 1, 3, 4, 5, 6 and 7 same as listed for Arctic Chamber.

(2) F-12 Low Stage Compressor

1 - Model 54 H Freon-12 Centrifugal compressor running at 5060 RPM driven through a Model CR-6 step up gear by a 350 HP 1200 RPM cynchronous motor. RW-105629.

APPENDIX I (Continued)

-3-

(8) F-12 Evaporator (Brine Cooler)

1 - 30" x 12'-6" horizontal shell and tube evaporator having trichloroethylene "brine" flowing through 3/4" O.D. Wolverine integral finned tubes in two brine passes. Freon-12 evaporates on the outside of the tubes. CW-24456.

III. Arctic Clothes Storage

(1) F-22 Low Stage Compressor

1 - Model A-15 Fuller Rotary Compressor

(2) F-22 High Stage Compressor

1 - 3HF4 Freon-22 condensing unit operating at 848 RPM driven by a 5 HP, 1750 RPM electric motor complete with a Model CDS-131 shell and tube type water cooled condenser.

(3) F-22 Receiver

1 - 6-5/8" x 6'-0" horizontal shell.

IV. Tropic Clothes Storage

(1) F-12 Condensing Unit

1 - Model 3HS4 Freon-12 condensing unit complete with compressor operating at 540 RPM driven by a 5 HP, 1750 RPM electric motor. Also included is a CDS 130 water cooled F-12 condenser with 8 pass heads.

APPENDIX I (Continued)

-4-

V. Rain Water System

(1) F-12 Evaporator

1 - "ACME" dry-ex Freon-12 water cooler DAE-153.

(2) Heat Exchanger

1 - "ACME" Model H 840 suction heat exchanger. (8¼" x 4'-0") of welded steel construction with finned copper tube coil baffled to permit counter flow of gas and liquid. C-3806.

(3) F-12 Compressor

1 - 3 HF-6 Compressor unit running at 800 RPM with Multi-V-Drive and driven by a 20 HP, 1750 RPM electric motor HR-8980.

(4) F-12 Oil Separator

1 - Vertical Freon Oil separator "ACME" Model FK-1525. B-3437.

(5) F-12 Condenser

1 - Model CDS-117 water cooled Freon-12 condenser with 4 pass heads HY-9489.

(6) F-12 Receiver

1 - "ACME" Model C-3510, 8-5/8" O.D. x 6'-0" horizontal Freon-12 receiver.

APPENDIX I (Continued)

-5-

VI. Arctic Ventilating - Air System

(1) Condensing Unit

1 - 4HF4 Freon-12 condensing unit operating at 658 RPM compressor speed, equipped with Multi-V-Drive and driven by a 25 HP, 1750 RPM electric motor. Also included is a Model CDS-131 Water cooled F-12 Condenser with 8 pass heads.

(2) Heat Exchanger

1 - Model H-840 "ACME" suction heat exchanger, 8¼" x 4'-0".

(3) F-12 Receiver

1 - 6-5/8" x 6'-0" horizontal shell.

(4) Oil Separator

1 - Vertical Freon-12 - Oil separator - "ACME" Model FK-1525.

VII. Tropic Ventilating - Air System

(1) Condensing Unit

1 - 4HF4 Freon-12 condensing unit operating at 658 RPM compressor speed, equipped with Multi-V-Drive and driven by a 25 HP, 1750 RPM electric motor. Also included is Model CDS-131 water cooled F-12 condenser with 8 pass heads.

APPENDIX I (Continued)

-6-

(2) Heat Exchanger

1 - Model H-840 "ACME" suction heat exchanger, 8-¼" x 4'-0".

(3) F-12 Receiver

1 - 6-5/8" x 6'-0" horizontal shell.

(4) Oil Separator

1 - Vertical Freon-12 Oil Separator - "ACME" Model FK-1525.

VIII. Arctic Chamber Dressing Room

(1) Condensing Unit

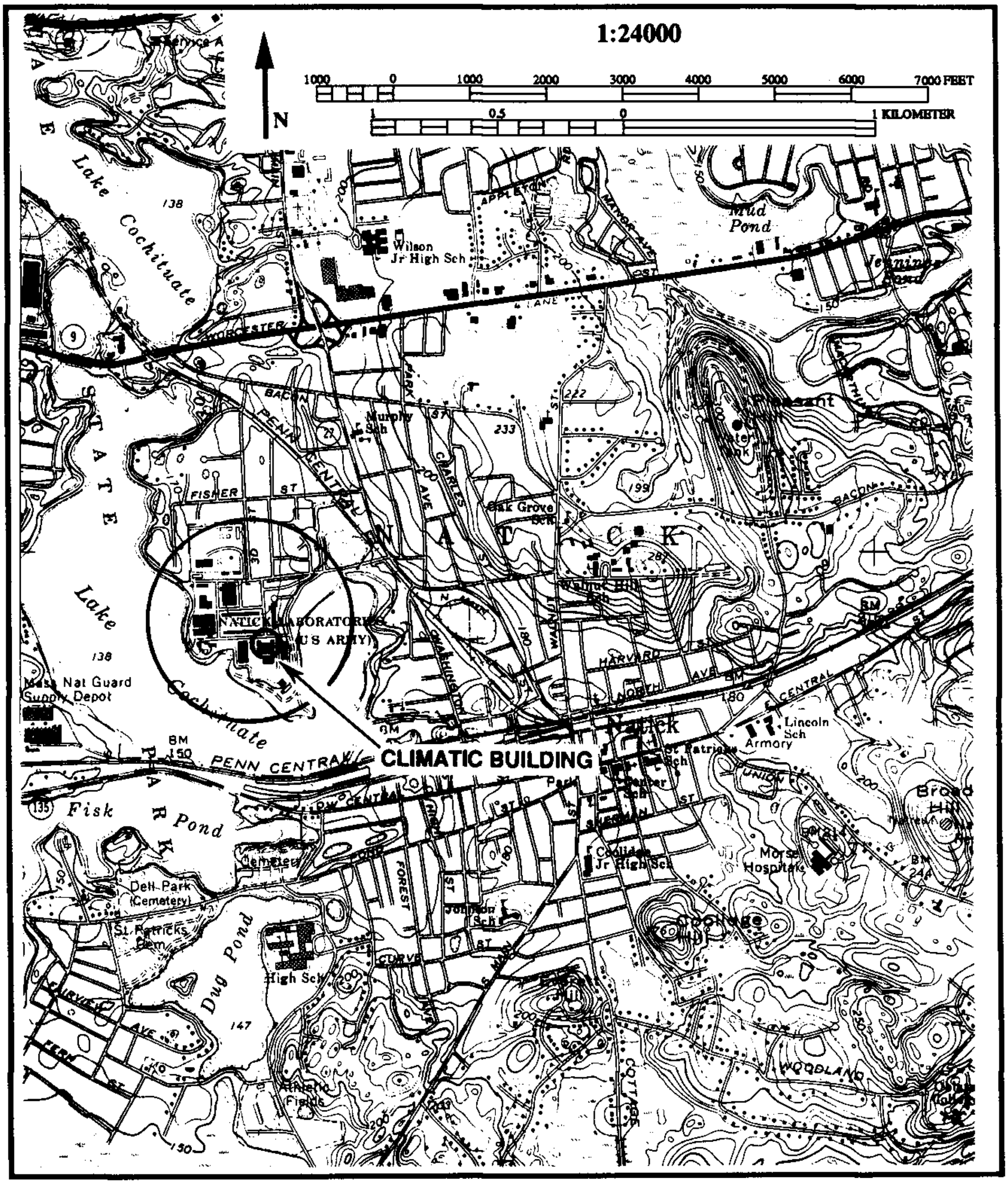
1 - 3HS2 -274 Freon-12 condensing unit operating at 654 RPM compressor speed, equipped with Multi-V-Drive and driven by a 5 HP, 1750 RPM electric motor. Unit includes a Model SDS-110 water cooled F-12 condenser with 8 pass heads.

IX. Tropic Chamber Dressing Room

(1) Condensing Unit

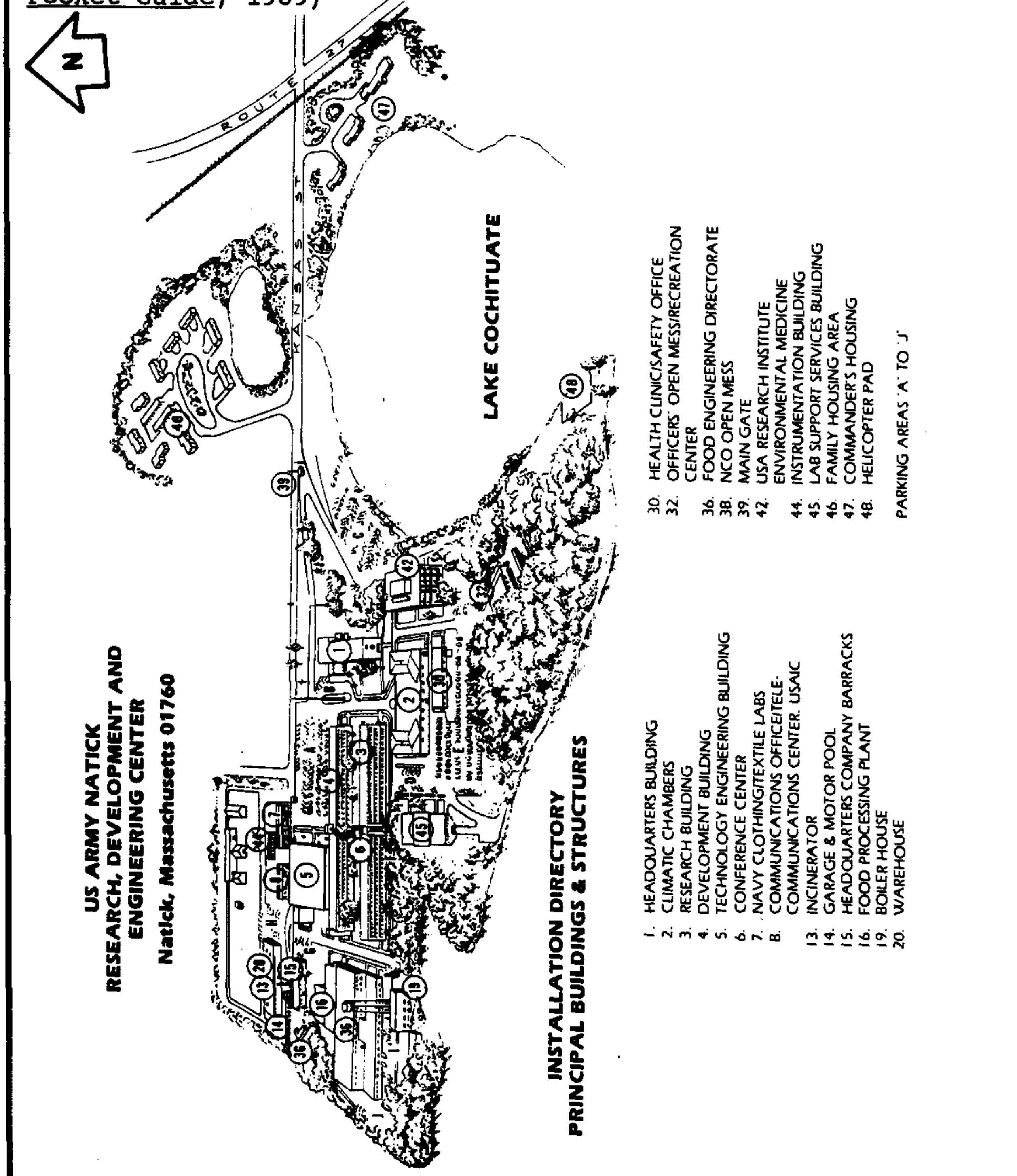
1 - 3 HS2 - 274 Freon-12 condensing unit operating at 654 RPM compressor speed, equipped with Multi-V-Drive and driven by 5 HP, 1750 RPM electric motor. Unit includes a Model CDS-110 water cooled F-12 condenser with 8 pass heads.

(USGS Natick, Mass. Quadrangle) **LOCATION MAP**



(Source: U.S. Army NRDEC, **FACILITY SITE PLAN**

Pocket Guide, 1989)



(Source: U.S. Army NRDEC) **FLOOR PLAN**